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Stereo Vision Based Automated Grasp Planning

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STEREO VISION BASED AUTOMATED GRASP PLANNING

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ABSTRACT

The department of Energy has a need for treating existing nuclear waste. Hazardous waste stored in old warehouses needs to be sorted and treated to meet environmental regulations. Lawrence Livermore National Laboratory is currently experimenting with automated manipulations of unknown objects for sorting, treating, and detailed inspection. To accomplish these tasks, three existing technologies were expanded to meet the increasing requirements. First, a binocular vision range sensor was combined with a surface modeling system to make virtual images of unknown objects. Then, using the surface model information, stable grasp of the unknown shaped objects were planned algorithmically utilizing a limited set of robotic grippers. This paper is an expansion of pervious work[1][2] and will discuss the grasp planning algorithm.

[1] The list of criteria will be detailed in a later section.

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INTRODUCTION

The grasp planning software examines the possible grasp position around an object for each available gripper and selects the most stable grasp position. The grasp planning software is divided into a grasp ranking system and a system to determine which grasps are worth investigating. To investigate all possible grasp position for all possible grippers would be computationally prohibitive. Therefore, a reduced set of all possible grasp positions is investigated. The surface modeling system simplifies and consolidate the description of objects as polygons and is used to reduce grasp planning computations. With this simplified object surface model, the grasp planner only investigates grasps perpendicular to the polygon surfaces. Since there are on average only 300 surfaces per object, the grasp investigation is computationally simplified. To rank the investigated grasp position, several measurements using the surface model are determine. A subset of the calculated parameters for grasp ranking are as follows:

- The distance of the gripper center to the centroid of the object

- The maximum angle between the gripper and an object planar surface under the gripper
- The maximum distance from the gripper to the object surface
- The minimum distance from the gripper to the object surface

From the calculated parameters above, a weighted summation of these measurements is used to rank grasps. The highest summation of weight measurements above a minimum threshold is assume to be a stable grasp position.

OBJECTIVE

The Grasp Planner System is used within the Intelligent Robotics Control task of the Mixed Waste Operations (MWO) Project. The objective of the Grasp Planner System is to provide the grasping technology in the robot simulation environment. Its requirements for the system include productivity, reliability, flexibility, and ease of use.

The Grasp Planner System targets the optimum grasp location to pick an unknown object, whether it is an individual object, or one among multiple objects. The waste objects can be laid on a platform at arbitrary locations. The objects can also be wrapped in plastic bags to simulate the waste materials that may be found in waste containers.

TECHNICAL APPROACH

The system designed to plan an optimal grasp for a robot to grasp an object is referred to as the Grasp Planner System. The technical approach considered the environment and communication of the Grasp Planner System, the graphical control of the system, the gripper operated by the planner, the construction of the surface models which simulate the waste objects, and how these models are used by the Grasp Planner System in order to generate different possible grasp positions, the seven criteria used by the system to rank the different possible grasp positions, the method of ranking the attainable grasp positions and finding the best grasp location, and the integration of the Grasp Planner System into the MWO Project. The Grasp Planner System as a process is detailed below.

Grasp Planner Environment and Communication

The autonomous Grasp Planner System has a vision-based grasping capability. A stereo vision range sensor is used to acquire a range image of an unknown waste object. A three-dimensional (3D) range data is obtained, and a surface model of that object is constructed. Grasp analysis is then performed on the surface model of the object.

The Grasp Planner System uses a single SGI computer platform to establish server communications to the MWO workcell model. This connection allows access to the surface model using the range image data. Inside the workcell, the Grasp Planner System interacts with the surface model of the object and the gripper, as well as the list of the grasp criteria which governs the direction of the grasp position.[1]

GRAPHICAL CONTROL PLATFORM

The Grasp Planner System uses Robline by CIMETRIX for its graphical control platform. It is used to construct the surface model of the waste objects and grippers, graphically illustrate grasp locations, and analyze each grasp position. The grasp analysis is used to obtain information on the seven criteria - collision detection, object clearance, centroid distance, gripper height, angular standard deviation, maximum clearance deviation, and surface contact. The information of the seven criteria will be used in the ranking process.

General Description of the Gripper

The gripper has a two-one interlocking configuration. Figure 1 is an illustration of the gripper with the edges of its fingers touching. The fingers are aligned in parallel axes, so that when the gripper is completely closed, the three fingers are interlaced. The interlacing characteristic is universal for the gripper types used by the Grasp Planner System. However the interface of the fingers may differ for each gripper type.

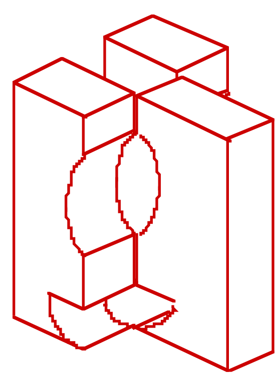


Figure 1

CONSTRUCTION OF SURFACE MODELS

The Grasp Planner System analyzes the surface model of the waste object in order to generate possible grasp positions. The surface model of an object consists of multiple extrusions within the Robline simulation package. An extrusion is a geometric tool used in Robline to transform a two-dimensional polygon into a 3D solid object by projecting the polygon along the z-axis. For example, a square projected through the z-axis makes a cubic extrusion. The size of the extrusions as well as the total number of extrusions making up an object can be modified by the user. Figure 2 is an image of a multi-sided surface model.

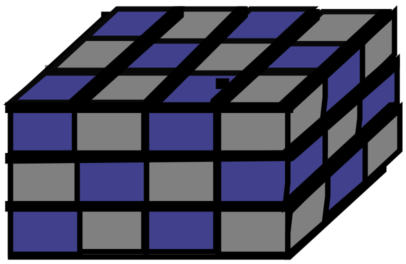


Figure 2.

Generation of Possible Grasp Locations

The Grasp Planner System generates several possible locations and orientation per extrusion for grasping an object. The number of possible grasps for each extrusion depends on the number of segments or sides in the polygon associated with that extrusion. A segment corresponds to a side on the polygon of an extrusion. There are two possible grasp locations generated by the Grasp Planner System for each segment. One grasp location can be described by placing one side of the gripper parallel to it as if the gripper is picking up the object from the top. The second grasp location can be described by placing one side of the gripper on top of the segment as if the gripper is picking up the object from its side. These two grasps are represented by Grasp 1 and Grasp 2 respectively, in Figure 3.

Criteria Used for Ranking the Possible Grasp Locations

The Grasp Planner System uses a list of criteria in order to rank a grasp position. Each attainable grasp is ranked based on these seven criteria. They are: 1) collision; 2) Object clearance; 3) Centroid distance; 4) Height of grasp; 5) Standard deviation of surface angle; 6) Maximum deviation of clearance; 7) Surface contact. Through analysis, a value corresponding to each criteria is obtained. These values are used in the Grasp Planner System's method of ranking.

For every grasp location generated by the Grasp Planner System, a collision check is performed between: i)the gripper and the waste object; and in the gripper and any interference objects. If a collision is detected, the grasp location currently
being analyzed is eliminated, and the next grasp position is tested.

The next criteria checked is the clearance between the gripper at its widest opening and the waste object. If the clearance is less than a minimum threshold, that grasp is also eliminated, and no further analysis is implemented. Below a maximum threshold, a grasp location with a wide clearance would have a higher (and better) rank than one with a narrow clearance. However, beyond the maximum threshold, there is a down grade in the ranking value. For example, if the clearance is wider than the maximum threshold, there is a possibility that one side of the gripper will turn or move the object from its original orientation while the gripper is in the process of grasping the object. This would lead to a possible unstable grasp.

If the grasp position being analyzed has passed the two previous tests (i.e. there is no collision, and the clearance is greater than the minimum threshold), the remaining criteria are evaluated and a ranking value is assigned to that grasp at the end of the analysis. This ranking value is a weighted sum of the values obtained for each criteria, and is calculated by the Grasp Planner System.

The next criteria measured is the distance between the centroid of the gripper and the centroid of the object. A grasp with the shortest centroid distance is the most stable grasp based on this criteria alone. This is because in most cases, once the object is picked up, there is less chance for the object to torque when the object is grasped near its centroid, than when it is grasped further away from its centroid.

The height of the grasp is also taken into account. This addresses the problem of having multiple objects randomly stacked on each other. It achieves the desired goal of picking the top object from a pile, by giving a high grasp a larger ranking value than a low grasp.

The next criteria, the standard deviation of the angles between the object's edge and the gripper's contact points, addresses the problem of grasping an object at its unsteady sides (i.e. jagged side). For example, in one case, (Grasp 1) the gripper is placed at the side where the object is shattered. The standard deviation in this case would be relatively high, compared to the case (Grasp 2) where the gripper is placed at an edge having somewhat of the same contour as the contacting surface of the gripper. This is shown in Figure 4, using a shattered cylindrical waste object.
Grasp 2 would have a higher rank value than Grasp 1 according to this criteria alone.

The maximum deviation of the clearance between the object edge and the gripper surface is the next criteria checked. This addresses the problem of having non-conforming edges as the contact point between the gripper and the waste object, which can lead to an unstable grasp. The maximum deviation is the difference between the maximum distance and the minimum distance. This is illustrated in Figure 5.

The arrows designate the varying distances between the object and the gripper. As one can see, a large maximum deviation
leads to an unstable grasp. Therefore, based on this criteria alone, Grasp 2 is more favorable.

The last criteria checked is the surface contact. This is evaluated by counting the number of extrusions in contact with the gripper at a particular grasp location. A grasp location yielding more surface contact (i.e. larger number of extrusions in contact with the gripper) would provide a more stable grasp. This is illustrated in Figure 6.

The white boxes designate extrusions that are in contact with the gripper. Based on this criteria, Grasp 2 provides a better grasp position.

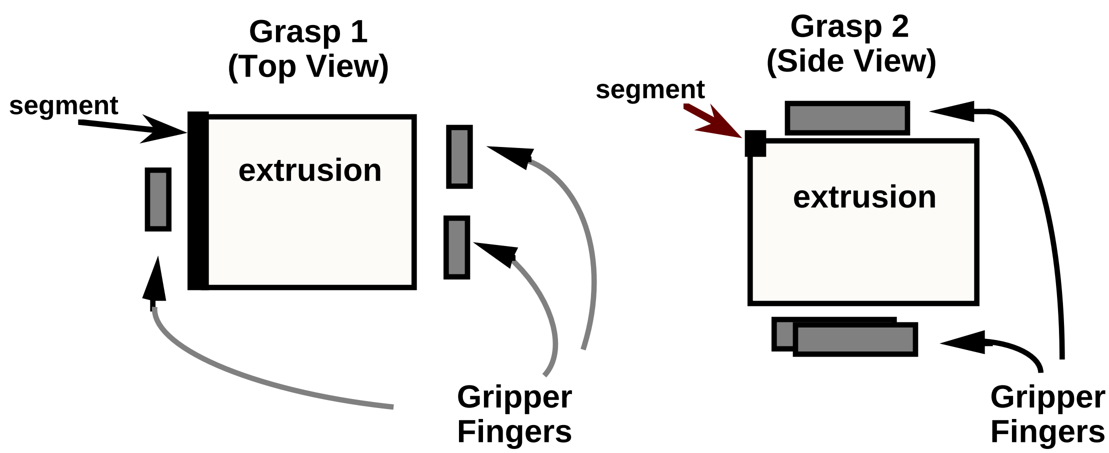
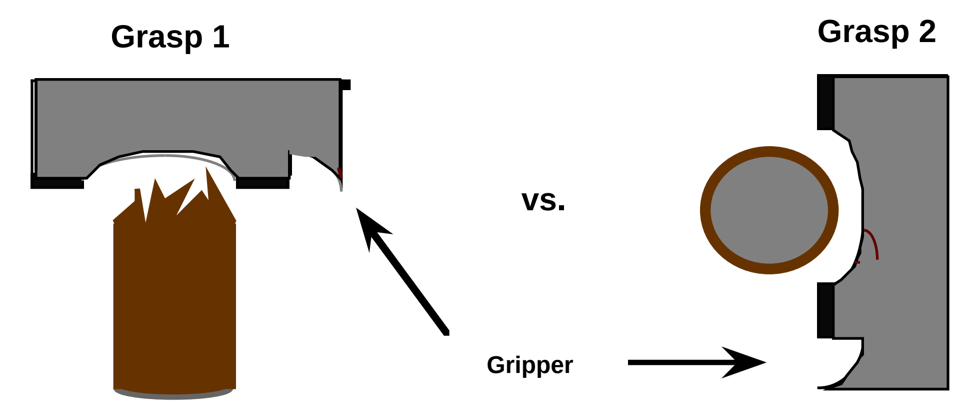


Figure 3.



(Side View) Figure 4. (Top View)

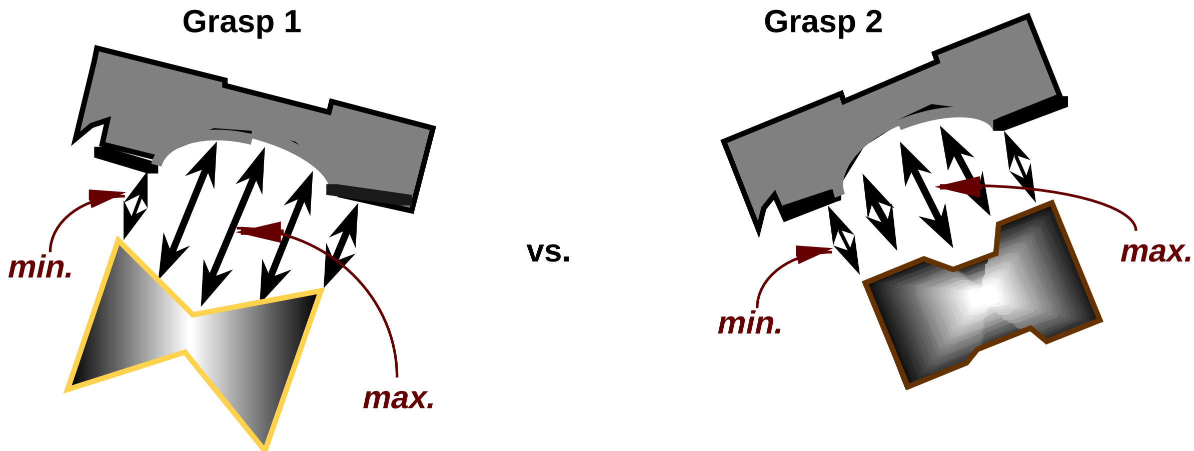


Figure 5.

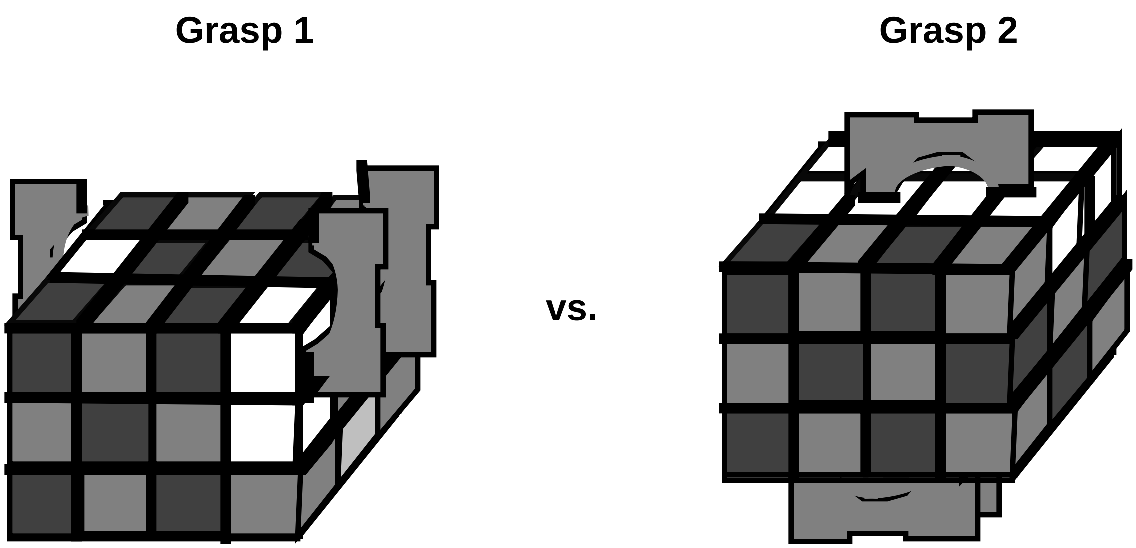


Figure 6.

RANKING

At the end of each grasp analysis, the grasp position is ranked based on a weighted summation of the seven criteria. Adjusting the relative weights of the values obtained from the seven criteria determines the best grasp location. These weights are user-defined and can easily be changed as desired. The best grasp position corresponds to the position with the highest ranking value.

Data Integration

The result of the Grasp Planner System analysis is used to drive the robot to pick the waste object at the location and orientation specified or indicated or calculated.

The weighting factor used in calculating the rank of each grasp position can be modified in order to improve the optimization of the grasp analysis. Modifying the weight factor of each grasp reflects a change in the method of ranking. For example if the weighting factor for the criteria of surface contact was increased so that it now has the largest weighting factor, then this criteria will be the most influential in choosing the best grasp position.

The process of finding exactly how important each criteria is in choosing the best grasp location can be done by performing a reality check - making a comparison between the ranking values produced by the Grasp Planner System, and the values obtained from manually measuring the stability of each grasp for each waste object. By doing this, one can check the efficiency of the Grasp Planner System, as well as modify the rank calculation, in order to improve the result of the reality check. The Grasp Planner System analysis is improved with agreement with the results obtained from manually checking the stability of each grasp.

MAJOR TECHNICAL ACCOMPLISHMENTS

The automated grasp planning system described allows for gasp ranking over an entire object using measured three dimensional surface models. This grasp ranking can compare multiple grippers and allows for the expansion to include new gripper designs. Since the grasp planner only uses the surface model of the workcell and grippers in the Robline environment to determine grasp ranking, the addition of new grippers only involves generating the new gripper surface model.

Another significant accomplishment is that this technique allowed for multiple application processes to share the same 3D surface modeling information by utilizing the common data structure, and using this data, these processes were executed in parallel.

FUTURE DEVELOPMENTS

For further development, the grasp planner system can be enhanced in several ways. One way is to add more ranking criteria into the grasp analysis. This can improve the optimization of the grasp planner. Furthermore, a sorting algorithm can be developed which will heuristically pick only a few of the possible grasp positions to be analyzed. This will speed up the process of finding an optimum grasp position because the grasp planner will only analyze those grasp positions which have the potential to be chosen as the best grasp.

In addition, the grasp planner is not necessarily restricted to the Mixed Waste Operations project. It can be applied to many other areas of application, such as biomedical technology, deep-sea salvage, space exploration, etc.

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